

1 **CLAIMS**

2 What is claimed, is:

3 (1) A compiler apparatus for collecting frequencies with which
4 each process is executed in a program to be optimized and
5 optimizing said program based on the collected frequencies,
6 said apparatus comprising:

7 a loop process detection portion for detecting a repeatedly
8 executed loop process of said program;

9 a loop process frequency collection portion for collecting loop
10 process frequencies with which said loop process is executed in
11 said program;

12 an in-loop process frequency collection portion for collecting
13 in-loop process frequencies with which, as against the number
14 of times of execution of said loop process, each of a plurality
15 of in-loop processes included in said loop process is executed;

16 an in-loop execution information generating portion for, based
17 on said loop process frequencies and said in-loop process
18 frequencies, generating in-loop execution information
19 indicating the frequencies with which each of said plurality of
20 in-loop processes is executed in the case where said program is
21 executed; and

22 an optimization portion for optimizing said program based on
23 said in-loop execution information generated by said in-loop
24 execution information generating portion.

25 (2) The compiler apparatus according to Claim 1, wherein said
26 in-loop process frequency collection portion collects said

1 in-loop process frequencies in the case where said loop process
2 frequencies are higher than a predetermined frequency.

3 (3) The compiler apparatus according to Claim 1, wherein said
4 in-loop execution information generating portion generates said
5 in-loop execution information by multiplying said loop process
6 frequencies by said in-loop process frequencies.

7 (4) The compiler apparatus according to Claim 1, wherein:

8 said loop process is an outer loop process including an inner
9 loop process which is a further inside loop process;

10 said loop process detection portion further detects said inner
11 loop process;

12 said loop process frequency collection portion collects the
13 loop process frequencies with which said inner loop process is
14 executed in said program based on said in-loop execution
15 information;

16 said in-loop process frequency collection portion further
17 collects the in-loop process frequencies of said inner loop
18 process; and

19 said in-loop execution information generating portion generates
20 the in-loop execution information on said inner loop process by
21 multiplying the in-loop process frequencies in said inner loop
22 process by said loop process frequencies of said inner loop
23 process.

24 (5) The compiler apparatus according to Claim 1, wherein:

25 said loop process frequency collection portion stops a counter

1 for determining the number of times of execution of said loop
2 process when said program is executed a predetermined number of
3 times so as to collect the number of times determined by the
4 counter as said loop process frequencies; and

5 said in-loop process frequency collection portion stops the
6 counter for determining the number of times of execution of
7 each of said plurality of in-loop processes when a total of
8 determined values of said plurality of in-loop processes
9 becomes the predetermined number of times.

10 (6) The compiler apparatus according to Claim 1, further
11 comprising:

12 a control flow graph generating portion for generating a
13 control flow graph in which each of a plurality of instruction
14 sequences in said program is generated as a node and an
15 execution order of said plurality of instruction sequences is
16 generated as a directed edge of said nodes;

17 a structure graph generating portion for, in said control flow
18 graph, generating an outline structure graph in which a single
19 loop node for showing said loop process in its entirety is
20 generated instead of a collection of the nodes forming said
21 loop process and an in-loop structure graph which is the
22 control flow graph of the collection of the nodes forming said
23 loop process; and

24 a counter insertion portion for, in each of said outline
25 structure graph and said in-loop structure graph, inserting a
26 counter into said program in order to count the number of times
27 of execution of each execution path in the structure graphs,
28 and wherein:

1 said loop process frequency collection portion generates as
2 said loop process frequencies the numbers of times of execution
3 of said loop node as against the numbers of times of execution
4 of said program; and

5 said in-loop process frequency collection portion collects as
6 said in-loop process frequencies the number of times of
7 execution of each execution path in said in-loop structure
8 graph as against the numbers of times of execution of said loop
9 process.

10 (7) The compiler apparatus according to Claim 6, wherein:

11 in the case where said program is executed a predetermined
12 number of times, said loop process frequency collection portion
13 collects as the loop process frequencies the determined values
14 of the counter inserted for counting the number of times of
15 execution of the execution paths including said loop node; and

16 in the case where a total of the determined values of said
17 plurality of in-loop processes becomes a predetermined number
18 of times, said in-loop process frequency collection portion
19 collects the in-loop process frequencies based on the
20 determined values of the counter inserted for counting the
21 number of times of execution of each execution path in said
22 in-loop structure graph.

23 (8) The compiler apparatus according to Claim 6, wherein in the
24 case where an insertion position in said program for inserting
25 the counter for determining the number of times of execution of
26 each execution path in said outline structure graph is the same
27 as the position in said program for inserting the counter for
28 determining the number of times of execution of each execution
29 path in said in-loop structure graph and then the counter of

1 one, at the most, of said outline structure graph and said
2 in-loop structure graph is started, said counter insertion
3 portion inserts into the insertion position the counter for
4 determining the numbers of times of execution of the execution
5 paths in both said outline structure graph and said in-loop
6 structure graph.

7 (9) The compiler apparatus according to Claim 6, wherein:

8 in the case where an insertion position in said program for
9 inserting the counter for determining the number of times of
10 execution of each execution path in said outline structure
11 graph is the same as the position in said program for inserting
12 the counter for determining the number of times of execution of
13 each execution path in said in-loop structure graph and then
14 the counter of one, at the most, of said outline structure
15 graph and said in-loop structure graph is started, said counter
16 insertion portion generates a plurality of determination
17 processes for determining the number of times of execution of
18 each execution path in each of said outline structure graph and
19 said in-loop structure graph; and

20 said in-loop process frequency collection portion inserts a
21 jump instruction for moving the process to another portion into
22 said insertion position and sets a jump destination of the jump
23 instruction at one of said plurality of determination processes
24 so as to determine the numbers of times of execution of the
25 execution paths in both said outline structure graph and said
26 in-loop structure graph.

27 (10) The compiler apparatus according to Claim 6, wherein:

28 said loop process is an outer loop process including an inner
29 loop process which is a further inside loop process;

1 said loop process detection portion further detects said inner
2 loop process;

3 in the control flow graph of said outer loop process, said
4 structure graph generating portion generates as an in-outer
5 loop structure graph a graph in which the single inner loop
6 node is generated instead of a collection of the nodes forming
7 said inner loop process and generates an in-inner loop
8 structure graph which is the control flow graph of the
9 collection of the nodes forming said inner loop process; and
10 said counter insertion portion further inserts the counter for
11 determining the number of times of execution of each execution
12 path in the in-inner loop structure graph;

13 said loop process frequency collection portion further collects
14 the loop process frequencies with which said inner loop process
15 is executed in said program based on said in-loop execution
16 information;

17 said in-loop process frequency collection portion collects the
18 frequencies of execution of each execution path in said
19 in-inner loop structure graph as the in-loop process
20 frequencies of said inner loop process as against the number of
21 times of execution of said inner loop process; and

22 said in-loop execution information generating portion further
23 generates the in-loop execution information on said inner loop
24 process by multiplying the in-loop process frequencies in said
25 inner loop process by the loop process frequencies of said
26 inner loop process.

27 (11) The compiler apparatus according to Claim 10, wherein, in
28 the case where an insertion position in said program for

1 inserting the counter for determining the number of times of
2 execution of each execution path in said in-outer loop
3 structure graph is the same as the position in said program for
4 inserting the counter for determining the number of times of
5 execution of each execution path in said in-inner loop
6 structure graph and then the counter of one, at the most, of
7 said in-outer loop structure graph and said in-inner loop
8 structure graph is started, said counter insertion portion
9 inserts into the insertion position the counter for determining
10 the numbers of times of execution of the execution paths in
11 both said in-outer loop structure graph and said in-inner loop
12 structure graph.

13 (12) The compiler apparatus according to Claim 10, wherein:

14 in the case where an insertion position in said program for
15 inserting the counter for determining the number of times of
16 execution of each execution path in said in-outer loop
17 structure graph is the same as the position in said program for
18 inserting the counter for determining the number of times of
19 execution of each execution path in said in-inner loop
20 structure graph and then the counter of one, at the most, of
21 said in-outer loop structure graph and said in-inner loop
22 structure graph is started, said counter insertion portion
23 generates a plurality of determination processes for
24 determining the number of times of execution of each execution
25 path in each of said in-outer loop structure graph and said
26 in-inner loop structure graph; and

27 said in-loop process frequency collection portion inserts a
28 jump instruction for moving the process to another portion into
29 said insertion position and sets a jump destination of the jump
30 instruction at one of said plurality of determination processes
31 so as to determine the number of times of execution of the

1 execution paths in both said in-outer loop structure graph and
2 said in-inner loop structure graph.

3 (13) A compiler program for causing a computer to function as
4 a compiler apparatus for collecting frequencies with which each
5 process is executed in a program to be optimized and optimizing
6 said program based on the collected frequencies, said program
7 causing said computer to function as:

8 a loop process detection portion for detecting a repeatedly
9 executed loop process of said program;

10 a loop process frequency collection portion for collecting loop
11 process frequencies with which said loop process is executed in
12 said program;

13 an in-loop process frequency collection portion for collecting
14 in-loop process frequencies with which, as against the number
15 of times of execution of said loop process, each of a plurality
16 of in-loop processes included in said loop process is executed;

17 an in-loop execution information generating portion for, based
18 on said loop process frequencies and said in-loop process
19 frequencies, generating in-loop execution information
20 indicating the frequencies with which each of said plurality of
21 in-loop processes is executed in the case where said program is
22 executed; and

23 an optimization portion for optimizing said program based on
24 said in-loop execution information generated by said in-loop
25 execution information generating portion.

26 (14) The record medium having the compiler program according
27 to Claim 13 recorded thereon.

1 (15) A compilation method for collecting frequencies with
2 which each process is executed in a program to be optimized and
3 optimizing said program based on the collected frequencies,
4 said method having:

5 a loop process detection step of detecting a repeatedly
6 executed loop process of said program;

7 a loop process frequency collection step of collecting loop
8 process frequencies with which said loop process is executed in
9 said program;

10 an in-loop process frequency collection step of collecting
11 in-loop process frequencies with which, as against the number
12 of times of execution of said loop process, each of a plurality
13 of in-loop processes included in said loop process is executed;

14 an in-loop execution information generating step of, based on
15 said loop process frequencies and said in-loop process
16 frequencies, generating in-loop execution information
17 indicating the frequencies with which each of said plurality of
18 in-loop processes is executed in the case where said program is
19 executed; and

20 an optimization step of optimizing said program based on said
21 in-loop execution information generated by said in-loop
22 execution information generating portion.

23 (16) A runtime information generating apparatus for collecting
24 frequencies with which each process is executed in a program to
25 be optimized, said apparatus having:

26 a loop process detection portion for detecting a repeatedly

1 executed loop process of said program;

2 a loop process frequency collection portion for collecting loop
3 process frequencies with which said loop process is executed in
4 said program;

5 an in-loop process frequency collection portion for collecting
6 in-loop process frequencies with which, as against the number
7 of times of execution of said loop process, each of a plurality
8 of in-loop processes included in said loop process is executed;

9 an in-loop execution information generating portion for, based
10 on said loop process frequencies and said in-loop process
11 frequencies, generating in-loop execution information
12 indicating the frequencies with which each of said plurality of
13 in-loop processes is executed in the case where said program is
14 executed, and

15 optimizing said program based on said in-loop execution
16 information generated by said in-loop execution information
17 generating portion.

18 (17) A runtime information generating program for causing a
19 computer to function as a runtime information generating
20 apparatus for collecting frequencies with which each process is
21 executed in a program to be optimized, said program causing
22 said computer to function as:

23 a loop process detection portion for detecting a repeatedly
24 executed loop process of said program;

25 a loop process frequency collection portion for collecting loop
26 process frequencies with which said loop process is executed in
27 said program;

1 an in-loop process frequency collection portion for collecting
2 in-loop process frequencies with which, as against the number
3 of times of execution of said loop process, each of a plurality
4 of in-loop processes included in said loop process is executed;
5 and

6 an in-loop execution information generating portion for, based
7 on said loop process frequencies and said in-loop process
8 frequencies, generating in-loop execution information
9 indicating the frequencies with which each of said plurality of
10 in-loop processes is executed in the case where said program is
11 executed, and

12 causing said program to be optimized based on said in-loop
13 execution information generated by said in-loop execution
14 information generating portion.

15 (18) A record medium having a runtime information generating
16 program according to Claim 17 recorded thereon.

17 (19) A computer program product comprising a computer usable
18 medium having computer readable program code means embodied
19 therein for causing collection of frequencies with which each
20 process is executed in a program to be optimized, the computer
21 readable program code means in said computer program product
22 comprising computer readable program code means for causing a
23 computer to effect the functions of claim 1.

24 (20) An article of manufacture comprising a computer usable
25 medium having computer readable program code means embodied
26 therein for causing collection of frequencies with which each
27 process is executed in a program to be optimized, the computer
28 readable program code means in said article of manufacture

1 comprising computer readable program code means for causing a
2 computer to effect the steps of claim 15.

3 (21) A program storage device readable by machine, tangibly
4 embodying a program of instructions executable by the machine
5 to perform method steps for collecting frequencies with which
6 each process is executed in a program to be optimized, said
7 method steps comprising the steps of claim 15.

8 (22) A computer program product comprising a computer usable
9 medium having computer readable program code means embodied
10 therein for causing collection of frequencies with which each
11 process is executed in a program to be optimized, the computer
12 readable program code means in said computer program product
13 comprising computer readable program code means for causing a
14 computer to effect the functions of claim 16.

15 (23) A runtime information generating method comprising:

16 collecting frequencies with which each process is executed in a
17 program to be optimized, said step of collecting frequencies
18 comprising:

19 detecting a repeatedly executed loop process of said program;

20 collecting loop process frequencies with which said loop
21 process is executed in said program;

22 collecting in-loop process frequencies with which, as against
23 the number of times of execution of said loop process, each of
24 a plurality of in-loop processes included in said loop process
25 is executed;

26 based on said loop process frequencies and said in-loop process

1 frequencies, generating in-loop execution information
2 indicating the frequencies with which each of said plurality of
3 in-loop processes is executed in the case where said program is
4 executed, and

5 optimizing said program based on said in-loop execution
6 information generated by said in-loop execution information
7 generating portion.

8 (24) An article of manufacture comprising a computer usable
9 medium having computer readable program code means embodied
10 therein for causing runtime information generation, the
11 computer readable program code means in said article of
12 manufacture comprising computer readable program code means for
13 causing a computer to effect the steps of claim 23.

14 (25) A program storage device readable by machine, tangibly
15 embodying a program of instructions executable by the machine
16 to perform method steps for runtime information generation,
17 said method steps comprising the steps of claim 15.